MS45XX AUTO-ZERO FUNCTION

APPLICATION NOTE

INTRODUCTION

This application note describes how to implement an auto-zero function when using PCB mounted digital pressure sensor MS45x5 with a microcontroller. Auto-zero is a compensation technique based on sampling the offset of the sensor at reference pressure (atmospheric pressure is a zero reference for a gauge measurement) in order to correct the sensor output for long term offset drift or variation.

Sources of offset errors are due to device to device offset variation (trim errors), mechanical stresses (mounting

Stresses), shifts due to temperature and aging. Performing auto-zero will greatly reduce these errors. The amount of error correction is limited by the resolution of MS45x5's internal A/D converter.

In pressure sensing applications where a zero-pressure reference condition can exist, auto-zero can be implemented easily when MS45x5 sensor is interfaced to an MCU.

Effect of Offset Errors

Figure 1 illustrates the transfer function of an integrated pressure sensor. It is expressed by the linear function:

$$V_{OUT} = V_{OFF} + [(V_{FSO} - V_{OFF}) / (P_{MAX} - P_{REF})] \times P = V_{OFF} + S \times P$$

Here, V_{OUT} is the voltage output of the sensor, V_{FSO} is the full-scale output, V_{OFF} is the offset, P_{MAX} is the maximum pressure and P_{REF} is the reference pressure. Note that ($V_{FSO} = -V_{OFF}/P_{MAX} - P_{REF}$) can be thought of as the slope of the line and V_{OFF} as they y-intercept. The slope is also referred to as the sensitivity, S, of the sensor.

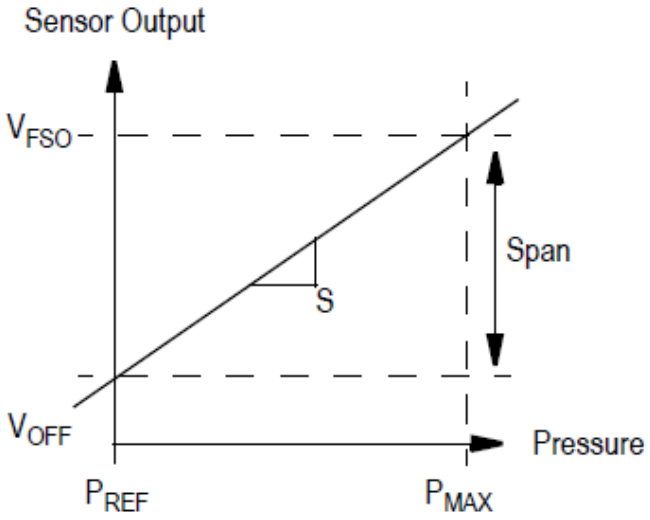

Figure1. Definition of Span, Full-Scale Output, Offset and Sensitivity

If the sensitivity and offset data given in the datasheet can be relied on, a linear equation can be used to determine the sensed pressure.

$$P = (V_{OUT} - V_{OFF})/S$$

If an offset error is introduced due to device to device variation, mechanical stresses, or offset shift due to temperature (the offset has a temperature coefficient or TCO), those errors will show up as an error, ΔP, in the pressure reading:

$$P + \Delta P = [V_{OUT} - (V_{OFF} + \Delta V_{OFF})]/S$$

As evident in Figure 2, offset errors, ΔVOFF, have the effect of moving the intercept up and down *without* affecting the sensitivity. *We can therefore correct this error by sampling the pressure at zero reference pressure (atmosphere) and subtracting this from the sensor output.*

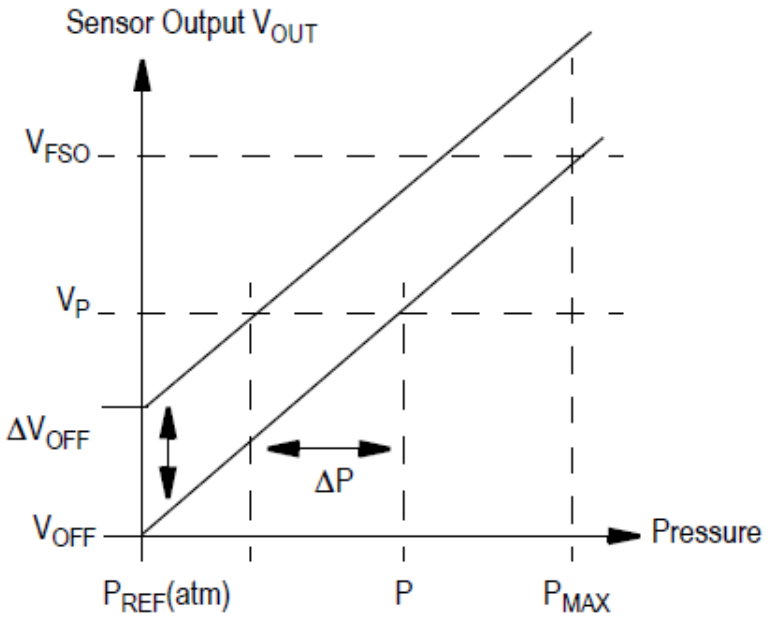

Figure 2. Effect of offset errors

Auto-Zero considerations in application

There is an important consideration when implementing auto-zero. In order to use this technique, *a zero pressure reference condition must be known to exist in the system.*

There are a lot of applications that will lend themselves naturally to auto-zeroing. Typical applications are those that:

- Experience a zero-pressure condition at system start up,
- Are idle for long time (zero pressure), take a pressure measurement then go back to idle again.

For example, in a water level measurement in a washing machine application, there is a zero pressure reference condition when the water in the tub is fully pumped out. Another application that is perfect for auto-zeroing is a beverage fill level measurement; a zero reference condition exists before the bottle is filled. HVAC air flow applications can also use auto-zeroing; before system startup, an auto-zero can be initiated. In other words, it can be used in applications where a zero pressure condition can exist in order to auto-zero the system. Remember that such a condition may exist in a product during its startup, or at its shutdown. The operation cycle should be scrutinized for auto-zeroing opportunities.

An auto-zero command can be automated by the system or can be commanded manually. Each system will have a different algorithm to command an auto-zero signal. For example, using the beverage fill level measurement as an example, the system will auto-zero the sensor before the bottle is filled.

There is a difference in Auto-zero and Factory Calibration. Although a product can be calibrated with auto-zero at the factory, variations in environment may cause the need for the product to be auto-zeroed just before usage. Continuous usage of Auto-zero can also lead to improved measurement than a one-time application.

A look up table can cause skewed results, the atmospheric pressure can differ from the factory location, or the particular temperature can shift in the customer's location. Auto-zero in the operating cycle will improve accuracy by compensating for these offset shifts.

Implementation of Auto-Zero with a Microcontroller

Auto-zero can be implemented easily when the integrated sensor is interfaced to a microcontroller. The auto-zero algorithm is listed below:

1. Sample the sensor output when a known zero reference is applied to the sensor (atmospheric pressure is a zero reference for gauge type measurement). Store current zero pressure offset as CZPO.
2. Sample the sensor output at the current applied pressure. Call this SP.
3. Subtract the stored offset correction, CZPO, from SP.

The pressure being measured is simply calculated as:

$$PMEAS = (SP - CZPO)/S$$

Note that the equation is simply a straight line equation, where S is the sensitivity of the sensor. The auto-zero algorithm is shown graphically in Figure 3.

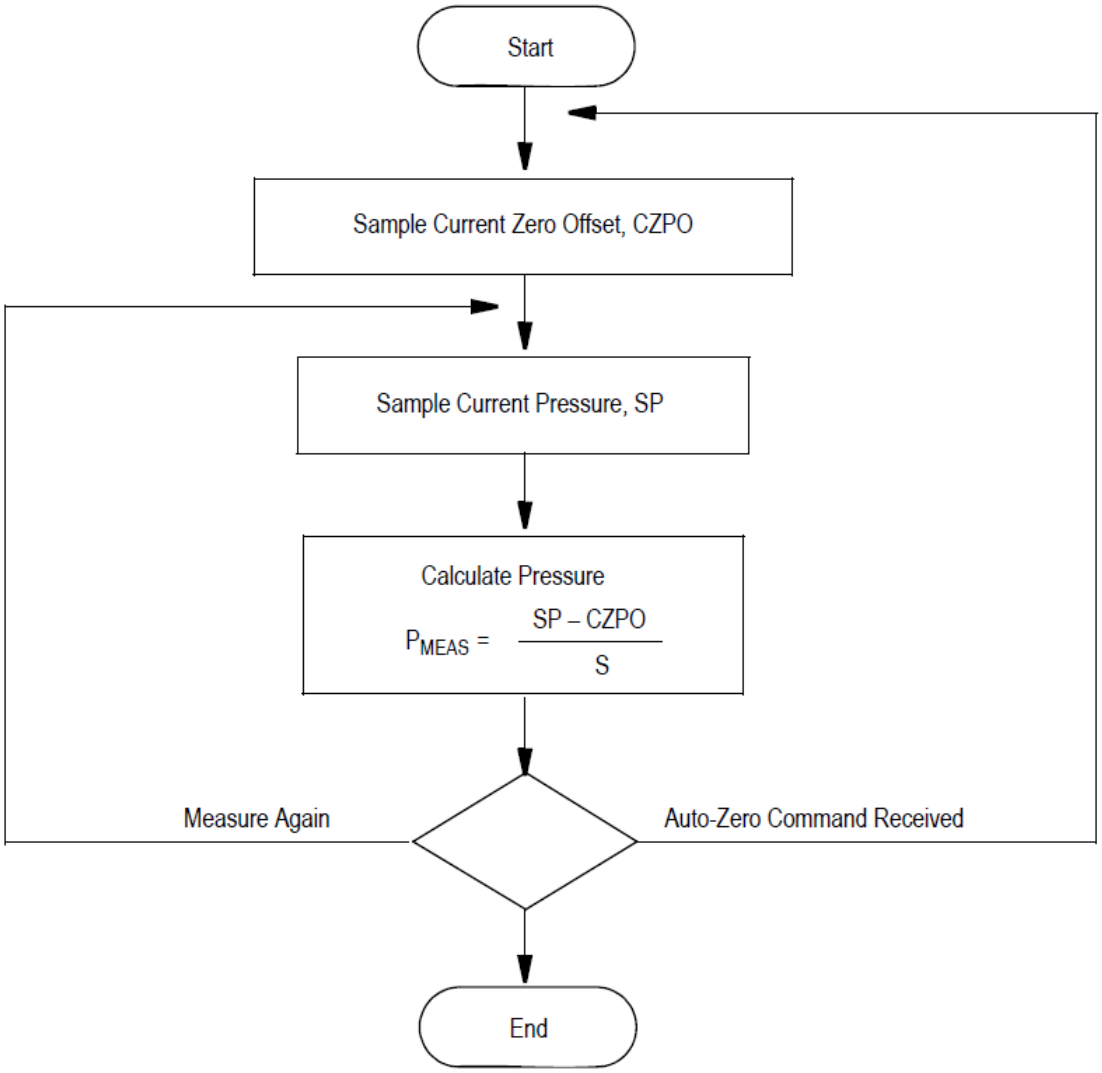

Figure 3. Flowchart of the auto-zero algorithm

If auto-zero is to be performed only once and offset correction data is stored in non-volatile memory, the TCO offset error and calibration error will not be corrected if the sensor later experiences a wide temperature range or later experience an offset shift. However, if auto-zero is performed *at* the operating temperature, TCO error will be compensated although subsequent offset calibration error will not be compensated. It is therefore best to auto-zero as often as possible in order to dynamically compensate the system for offset errors.

Conclusion

Auto-zero can be used to reduce offset errors in a sensor system. This technique can easily be implemented when an integrated pressure sensor is interfaced to a microcontroller. With a few lines of code, the offset errors are effectively reduced; the resulting offset error reduction is limited only by the resolution of the MS45x5 internal A/D

NORTH AMERICA
Measurement Specialties, Inc.,
a TE Connectivity company
45738 Northport Loop West
Fremont, CA 94538
Tel: +1 800 767 1888
Fax: +1 510 498 1578
customercare.frmt@te.com

EUROPE
MEAS Switzerland Sarl,
a TE Connectivity company
Ch. Chapons-des-Prés 11
CH-2022 Bevaix
Tel: +41 32 847 9550
Fax: +41 32 847 9569
customercare.bevx@te.com

ASIA
Measurement Specialties (China) Ltd.,
a TE Connectivity company
No. 26 Langshan Road
Shenzhen High-Tech Park (North) Nanshan District,
Shenzhen, 518057
China
Tel: +86 755 3330 5088
Fax: +86 755 3330 5099
customercare.shzn@te.com

te.com/sensorsolutions